Freezer Storage Effects on Beef Prepared by an Interrupted Cooking Procedure

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SUMMARY

The effects of freezer storage, alone or in combination with either antioxidant dip or vacuum packaging, on quality of beef prepared by an interrupted cooking procedure were investigated. This "roasteak" method involved preroasting boneless chuck rolls to an internal temperature of 110°F (43°C), chilling the roasts overnight in a refrigerator, slicing them, and broiling the slices quickly just before serving.

The "roasteak" procedure can be recommended as a convenience form of cooked beef. The slices from the preroasted meat can be frozen prior to broiling, and the quality can be protected by dipping the slices in a solution of antioxidant such as sodium tripolyphosphate and sodium ascorbate before freezing.

The sensory panel considered samples of beef prepared by all variations of the "roasteak" procedure acceptable even after one year of storage (-7 ± 3°F). After nine mo of storage, a decline in quality, as indicated by the aroma, flavor, and general acceptability scores, was observed for the frozen untreated samples. Mean panel scores for treatment indicated that control samples of beef were significantly better than frozen untreated and vacuum packaged slices that had been held in frozen storage prior to broiling. However, means for flavor, tenderness, juiciness, and general acceptability for antioxidant-treated meat were higher than for frozen untreated samples. No significant differences occurred in mean scores for sensory evaluations between antioxidant dipped and vacuum packaged or between vacuum packaged and frozen untreated "roasteaks." No significant correlations were found between the data obtained by sensory and TBA tests. TBA numbers were low for meat, even after one year of storage.

INTRODUCTION

No doubt the trend toward convenience foods will increase in the next few years if quality is offered along with convenience. Interrupted cooking procedures for meats introduce convenience by providing for part of the cooking to be done at a time when other pressures for meal preparation are at a minimum, by releasing some of the time just prior to service of meals, and by allowing for scheduling of ovens for foods other than meat in the hours just before meal service.

Previous research showed that U. S. Good grade shoulder clod and chuck roll roasts of beef were acceptable in flavor, tenderness, and general acceptability when prepared by the "roasteak" procedure. For this procedure, the meat was roasted at 300°F (149°C) to an internal temperature of 110°F (43°C) or 120°F (49°C) and refrigerated overnight. Then the meat was sliced and the slices were broiled 3 min per side. Although differences were not significant, slices from the roasts cooked to 110°F were judged better in palatability characteristics than were those from cuts preroasted to 120°F. When the "roasteak" procedure was modified by freezing the preroasted slices of chuck roll before broiling, average taste panel scores decreased for flavor, tenderness, and general acceptability (Korschgen *et al.*, 1963).

The "roasteak" procedure was also evaluated for U. S. Good grade bottom rounds of beef (Korschgen *et al.*, 1964). The following modifications of the procedure were included: (1) slices from chilled preroasted rounds, wrapped individually in laminated freezer paper and stored in a home type freezer until broiled; (2) slices from blast-frozen preroasted rounds wrapped individually in laminated freezer paper for freezer storage until broiled; and (3) slices from the blast-frozen roasts wrapped individually in laminated freezer paper for freezer storage and broiled with or without prior defrosting. Mean taste panel scores for beef prepared by the standard procedure, and all modifications, indicated that the meat was liked regardless of treatment. However, mean taste panel scores were higher for flavor, tenderness, juiciness, and general acceptability for slices from bottom rounds of beef when they were cooked by the standard procedure than for any modification where the preroasted slices were subjected to freezer

Table 1. Summary of mean[1] weights, cooking losses, time required to reach internal temperature of 110°F (300°F oven), subsequent rise in internal temperature and yield for chuck roll roasts.

	Mean	Range
Raw weight	15.2 lbs	12.5–18.3 lbs
Cooked weight	12.7 lbs	10.0–15.3 lbs
Total cooking loss	16.8%	14.4–23%
Drip	2.5%	1.5– 4.2%
Evaporation	14.3%	11.9–19.1%
Cooking time	14.3 min/lb	10.3–17.9 min/lb
Rise in internal temperature after removal from oven	18.7°F	10 –26°F
Yield per roast	17 11/16 inch slices	14 –19 11/16 inch slices

[1] N = 24.

storage. Warner-Bratzler shear values for 1-in cores followed the same trend as taste panel scores.

Versatility of this procedure would be enhanced if slices of precooked meat could be held in freezer storage without loss of quality prior to serving. The purpose of this study was to evaluate the effectiveness of antioxidant and of vacuum packaging in protecting quality of preroasted slices of beef chuck roll held in freezer storage up to one year.

EXPERIMENTAL

Meat preparation. Twelve paired U. S. Good grade chuck roll roasts were obtained for this study. One of each pair was preroasted to 110°F and sliced 11/16-in thick. These slices were used for the "roasteak" frozen samples. The second roast from each pair was preroasted and stored (39–44°F, 3.9–6.7°C) one day before evaluations by the taste panel. Slices from these roasts were designated as control samples. All preroasted slices were broiled just prior to chemical and sensory testing.

Pairs composed of adjacent slices were removed from each roast and assigned randomly to treatment. One of each pair of slices was used for chemical and the other for sensory testing. Each treatment was replicated three times for each storage period. With the exception of the control, all samples were placed in polymylar bags, closed with aluminum bands applied by Cryovac machine Model CGC (Cryovac Division, W. R. Grace and Co., Duncan, S. C.) and frozen. The treatments were as follows:

(1) Slices were packaged in polymylar bags and frozen without further treatment.
(2) Slices were immersed in antioxidant solution (10 g $Na_5P_3O_{10}$ and 2.7 g $C_6H_7O_6Na$ brought to 1 L volume with distilled water) and drained for 10 sec before packaging in polymylar bags and freezing.
(3) Slices were vacuum packaged in polymylar bags before freezing.
(4) Meat for control samples was preroasted, refrigerated overnight, and sliced and broiled just before taste panel evaluations.

Storage periods. Slices from the preroasted meat were kept in frozen storage at −7 (±3)°F for 1 day, 1, 3, 6, 9, and 12 mo. Twelve slices from one roast and six slices from another were assigned to each frozen storage period.

Preparing and serving samples to taste panel. Slices of meat from frozen storage were placed, while frozen, on an electric grill with the thermostat set at 300°F (149°C) and broiled for 11 min on one side and 5 min on the other. Fresh control slices were grilled for 3 min per side at 400°F (204°C). Six cubes, approximately ½-in square, were cut from the center of each slice for sensory evaluation. These cubes were dropped into sand-bath preheated 50-ml beakers. The beakers were capped immediately with squares of aluminum foil. A taste panel of six members judged samples of meat for aroma, flavor, tenderness, juiciness, and general acceptability on a 9-point hedonic scale with 9, "like extremely," 5 "neither like nor dislike," and 1, "dislike extremely." Each judge received a cube of meat from the same position from each "roasteak." Only one cube was presented at a time. The order of preparing and serving samples was randomized. A warm-up sample from the control meat was served at the beginning of each tasting session.

Chemical analyses. "Roasteaks" for chemical analyses were broiled as for taste panel and were frozen immediately on slabs of dry ice. This frozen meat was ground three times along with chips of dry ice. Portions of the ground meat were used immediately for the 2-thiobarbituric acid (TBA) analysis as described by Witte (1966). Duplicate extractions were made on each slice of meat, and two colorimetric analyses were completed on each extraction.

Triplicate determinations of fat were made on the broiled meat from each animal represented in the study. The modified Babcock method for fat analysis was used (A.O.A.C., 1964).

Statistical analyses. Analyses of variance, correlation coefficients, and least square differences were computed on the data (Steel *et al.*, 1960). Duncan's multiple range tests were used where significant differences were found by analysis of variance (Duncan, 1955).

RESULTS AND DISCUSSION

Meat prepared by "roasteak" procedure. As shown in Table 1, the average raw weight of the chuck roll roasts was 15.2 lbs. The mean time required to reach an internal temperature of 110°F was 14.3 min/lb, with a range of 10.3 to 17.9. This wide range of cooking time emphasized the need for a thermometer to gauge the degree of doneness for the "roasteak" procedure. Though the selected internal temperature for the preroast was 110°F, the maximum mean temperature attained after the roasts were removed from the oven was 128.7°F (53.7°C).

Mean total cooking loss as a result of preroasting was 16.8% (Table 1). Of this amount, 2.5% was due to drip, and 14.3% was due to evaporation. These data cannot be compared precisely with those for a conventional roasting method because additional losses occur when slices of "roasteak" are broiled. Previous work indicated that loss due to broiling averaged 22.4% (Korschgen *et al.*, 1963).

An average of 17 slices (11/16-in thick) was obtained from the roasts prepared in this study (Table 1). One slice would yield two servings, approximately 6 oz each.

The level of fat ranged from 5.4 to

Table 2. Mean[1] percent fat for cooked meat from each animal included in study.

Animal number	Percent fat	Storage period assignment
6	12.7	1 day
9	20.1	1 day
13	15.6	1 month
3	16.2	1 month
5	17.0	3 months
12	16.6	3 months
2	11.5	6 months
7	5.4	6 months
1	16.0	9 months
4	19.6	9 months
8	18.1	12 months
11	16.0	12 months

[1] N = 3.

20.1% for the meat from the different animals (Table 2). Random assignment of the meat from different animals to storage period is illustrated in Table 2 so comparison between tables could be made.

Effect of treatment and storage on palatability. A summary of mean panel scores for aroma, flavor, tenderness, juiciness, and general acceptability for beef prepared by variations of the "roasteak" method is given in Table 3. Though the mean score for all palatability characteristics for all treatment-storage combinations ranged from 4.8 to 7.7, only one mean (4.8, flavor of frozen untreated samples after nine mo of storage), was below the acceptable level.

Sensory scores for aroma declined significantly for the frozen untreated samples after nine mo of storage (Table 3. This trend toward lowered scores that remained low was not reflected in other frozen-treatment samples. One explanation for lack of significant decline in aroma with increased storage time may be the lack of sufficient oxidation to produce off-odors. On the other hand, this phenomenon may be related to the cooking method employed in the "roasteak" procedure. It has been pointed out that the carbonyl compounds, the secondary by-products of autoxidation, are responsible for the off-flavors and odors of stored meats (Lea, 1962). These odorous fission products may be volatilized during the boiling of the slices of beef just prior to panel evaluation. No appreciable drop in panel scores for flavor and general acceptability for meat dipped in antioxidant or those vacuum packaged was noted between storage periods as storage time increased. The flavor and general acceptability of the frozen untreated samples were significantly lower after nine mo of storage than after one day. There was no trend toward increasing or decreasing scores for tenderness or juiciness as storage time lengthened (Table 3).

Analyses of variance for taste panel scores for all attributes for the beef prepared in this study appear in Table 4. The interaction of storage period and judges (SP×J) was significant for all characteristics. This significant interaction indicated that panel members were inconsistent in scoring meat from the same treatment in the same manner after each storage period. Whether the inconsistency was due to lack of discrimination or to the confounding effect of animal variation with storage period cannot be determined with this design.

With the exception of tenderness, the interaction of storage period and treatment (SP×T) was not significant for any attribute. Therefore, it can be assumed that storage had no effect on treatment. However, the main effects of storage and of treatment were significant for all palatability characteristics (Table 4).

Significant differences between mean panel scores for treatments of "roasteak" are indicated in Table 5. The score for aroma was significantly higher for the control meat than for the samples from all other treatments, which were not significantly different from each other. Since the aroma of the antioxidant treated meat did not differ significantly from the vacuum packaged or frozen untreated samples, the sodium tripolyphosphate plus sodium ascorbate dip apparently did not contribute to off-odors as suggested by Ramsey *et al.* (1963).

The mean sensory score for flavor was significantly higher for the control sample than the mean flavor ratings for meat from all other treatments. In addition, the mean flavor score of the frozen untreated sample was significantly lower than scores for the antioxidant treated and vacuum packaged beef (Table 5).

The interaction of storage period and treatment (SP×T) was significant for tenderness (Table 4). Therefore, a comparison between treatments for this attribute would not be meaningful and is not included in Table 5.

The mean panel ratings for both juiciness and general acceptability for control samples of "roasteak" were not significantly different from those for the antioxidant dipped samples, but were significantly higher than mean scores for vacuum packaged and frozen untreated meat. Though the mean sensory scores both for juiciness and general acceptability of the beef did not differ significantly between anti-

Table 3. Summary of means[1] of taste panel scores[2] for palatability characteristics of beef prepared by variations of the "roasteak" procedure.

Attribute	Treatment	Storage periods: 1 day	1 mo	3 mo	6 mo	9 mo	12 mo
Aroma $LSD_{.05} = 0.36$	Frozen, untreated	6.0	5.8	6.0	5.8	5.4	5.4
	Frozen, antioxidant dipped	6.1	5.8	6.8	5.9	5.6	5.8
	Frozen, vacuum packaged	5.7	5.7	6.9	5.9	5.5	5.7
	Control	6.0	6.4	7.1	6.0	6.7	6.2
Flavor $LSD_{.05} = 0.96$	Frozen, untreated	6.3	5.9	6.1	5.3	4.8	5.1
	Frozen, antioxidant dipped	6.6	6.4	7.4	6.2	5.3	6.0
	Frozen, vacuum packaged	5.9	6.4	7.4	5.8	5.1	5.7
	Control	6.4	6.9	7.5	6.5	7.2	6.6
Tenderness $LSD_{.05} = 0.77$	Frozen, untreated	6.7	6.4	6.3	5.7	6.1	6.0
	Frozen, antioxidant dipped	7.1	6.3	7.7	6.1	6.3	6.8
	Frozen, vacuum packaged	5.9	6.2	7.2	6.2	6.2	5.9
	Control	6.4	6.8	7.4	6.4	7.1	6.4
Juiciness $LSD_{.05} = 0.80$	Frozen, untreated	6.7	6.7	6.6	5.6	6.0	6.4
	Frozen, antioxidant dipped	7.1	6.5	7.6	6.4	6.1	6.7
	Frozen, vacuum packaged	6.3	7.0	7.3	5.8	6.1	6.3
	Control	6.7	7.1	7.7	6.6	7.0	6.6
General Acceptability $LSD_{.05} = 0.85$	Frozen, untreated	6.4	6.1	6.2	5.7	5.3	5.4
	Frozen, antioxidant dipped	6.8	6.2	7.4	6.1	5.8	6.2
	Frozen, vacuum packaged	6.1	6.5	7.2	5.9	5.5	5.8
	Control	6.4	6.8	7.4	6.4	7.1	6.4

[1] N = 18.
[2] Range of scores: 9, "like extremely," to 1, "dislike extremely."

Table 4. Summary of analyses of variance of taste panel scores for palatability characteristics of beef prepared by variations of the "roasteak" procedure.

Source of variation	Degrees of freedom	Mean square: Aroma	Flavor	Tenderness	Juiciness	General acceptability
Storage periods (SP)	5	8.6986**	20.2926**	9.5333**	12.5133**	14.0981**
Treatments (T)	3	8.6505**	30.1173**	9.1636**	7.7677**	16.2531**
Replications (R)	2	3.4444	11.0023**	3.2569	2.5278	6.2315*
Judges (J)	5	28.9208**	39.8259**	20.9722**	26.1375**	36.1204**
SP × T	15	1.2579	3.0765	2.3840*	1.7215	2.0623
SP × J	25	2.2519**	3.6259*	2.3956*	2.3253*	3.5393**
Error	373	1.2359	2.1711	1.3929	1.4904	1.7084
Total	431	1.7652	3.1695	1.8699	2.0092	2.4921

** $P<0.01$.
*$P<0.05$.

Table 5. Treatment means[1,2] for panel scores[3] for palatability characteristics of beef prepared by variations of the "roasteak" procedure.

Attribute	Treatment: Control	Frozen, antioxidant dipped	Frozen, vacuum packaged	Frozen, untreated
Aroma	6.4^{a}	6.0^{b}	5.9^{b}	5.8^{b}
Flavor	6.9^{a}	6.3^{b}	6.1^{b}	5.6^{c}
Juiciness	6.9^{a}	6.7^{ab}	6.5^{bc}	6.3^{c}
General acceptability	6.8^{a}	6.4^{ab}	6.2^{bc}	5.8^{c}

[1] N = 108.
[2] Where exponent letters differ within a line, mean scores differ significantly ($P<0.05$) from each other. Exponent letters have no meaning in themselves (Duncan, 1955).
[3] Range of scores: 9, "like extremely," to 1, "dislike extremely."

Table 6. Means[1,2] for panel scores[3] for palatability characteristics of beef prepared by the "roasteak" procedure and stored at (−7 ± 3°F) for different lengths of time.

Attribute	Storage periods: 1 day	1 mo	3 mo	6 mo	9 mo	12 mo
Aroma	5.98^{b}	5.79^{b}	6.57^{a}	5.87^{b}	5.50^{b}	5.63^{b}
Flavor	6.26^{b}	6.22^{b}	6.98^{a}	5.78^{bc}	5.19^{c}	5.61^{bc}
Tenderness	6.57^{ab}	6.28^{b}	7.07^{a}	6.00^{b}	6.20^{b}	6.24^{b}
Juiciness	6.70^{ab}	6.72^{ab}	7.16^{a}	5.94^{c}	6.06^{c}	6.48^{bc}
General acceptability	6.41^{ab}	6.26^{b}	6.96^{a}	5.87^{bc}	5.54^{c}	5.92^{bc}

[1] N = 54.
[2] Where exponent letters differ within a line, mean scores differ significantly ($P<0.5$) from each other. Exponent letters have no meaning in themselves (Duncan, 1955).
[3] Range of scores: 9, "like extremely," to 1, "dislike extremely."

Table 7. Analysis of variance of TBA numbers for beef prepared by variations of the "roasteak" procedure.

Source of variation	Sum of squares	Degrees of freedom	Mean square
Replication (R)	0.0446	2	0.0223
Storage period (SP)	2.4678	5	0.4936**
Treatment (T)	0.7742	3	0.2581**
Fresh control × all other treatments (A)	0.0020	1	0.0020
Frozen control × antioxidant dipped and vacuum packaged (B)	0.6794	1	0.6794**
Antioxidant dipped × vacuum packaged (C)	0.0927	1	0.0927
SP × T	0.9291	15	0.0619**
SP × A	0.1685	5	0.0337
SP × B	0.7156	5	0.1431**
SP × C	0.0488	5	0.0098
Error	1.1175	46	0.0243
Extracts	0.1710	72	0.00237
Determinations	0.0802	144	0.00056
Total	5.5844	287	

**$P<0.01$.

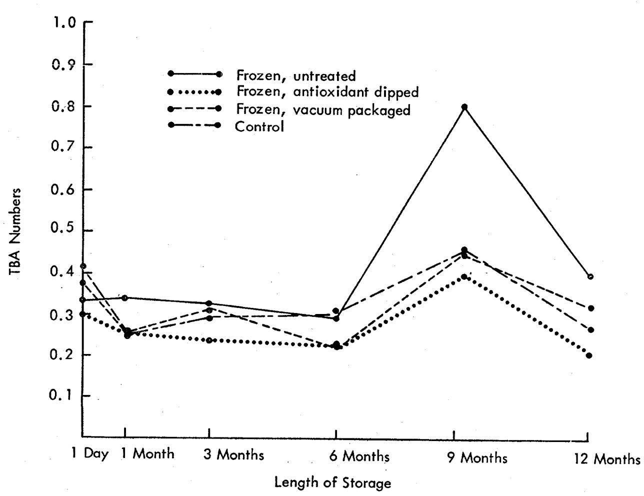

Fig. 1. Trends in mean TBA numbers determined for beef prepared by variations of the "roasteak" procedure.

oxidant dipped and vacuum packaged samples, only the mean scores for antioxidant samples were significantly higher than those for the frozen untreated samples (Table 5).

The trend for mean sensory scores for all attributes for "roasteak" samples was in the following order of descending value: control, antioxidant dipped, vacuum packaged, and frozen untreated. Although the frozen untreated slices were acceptable, panel scores for these samples were significantly lower than for control "roasteaks" for all attributes. Thus it appears that some protective measure is desirable for "roasteaks" held in freezer storage. The samples dipped in antioxidant solution were rated significantly higher in flavor, juiciness, and general acceptability than the frozen untreated slices (Table 5).

Table 6 includes only the means for panel scores for meat subjected to storage. Mean scores for the samples of "roasteak" stored three mo were significantly higher for aroma and flavor than mean scores for meat evaluated at any other storage period. There is no adequate explanation for this. It was pointed out previously that effect of animal variation was confounded with storage period in this experimental design, even though paired roasts from carcasses were assigned at random to each storage period. Examination of the raw data revealed that the palatability scores were fairly consistent for all replicates obtained from the two carcasses for this storage period.

Effect of treatment and storage on TBA numbers. As shown in Table 7, significant differences were found among TBA numbers for storage period (SP), treatment (T), and interaction between storage period and treatment (SP × T). Because of this significant interaction, the differences due to main effects are not too meaningful. Partitioning the sums of squares of this interaction into orthogonal comparisons revealed that the three treatments subjected to freezing interacted with storage period (SP×B).

Partitioning the sums of squares of treatment into orthogonal contrasts indicated significant differences neither between TBA numbers for control "roasteak" and all frozen treatments (A) nor between the TBA values of the samples dipped in antioxidant and the vacuum packaged slices of meat (C). However, the mean TBA number for the frozen untreated beef was significantly higher than for the combined means of the TBA numbers of

Table 8. Correlation coefficients between mean[1] TBA numbers and mean sensory scores for all treatments of beef prepared by variations of the "roasteak" procedure.

Attribute	Storage periods 1 day	1 mo	3 mo	6 mo	9 mo	12 mo
Aroma	0.19	0.39	−0.19	0.32	−0.26	−0.50
Flavor	0.15	0.15	−0.10	0.32	−0.33	−0.45
General acceptability	0.04	0.27	−0.29	0.24	−0.33	−0.54

[1] N = 12.

antioxidant dipped and vacuum packaged "roasteak" slices (B).

The effects of storage and treatment on TBA numbers are shown in Fig. 1. TBA numbers for the meat from the nine-mo storage period were higher for all treatments than for any other storage period. Although differences were not significant for this period, the palatability scores for flavor also tended to be low for meat subjected to freezing (Table 3).

Witte (1966) and Chang *et al.* (1961) stated that freezing and thawing of meat lowered the TBA values. Also, Buttkus (1967) found that malonaldehyde reacted very readily with E-amino groups of myosin at −20°C. He attributed the high rate of reaction in the frozen system to concentration and catalytic effects involving the ice structure. In this experiment, the meat from all frozen variations of the "roasteak" method was subjected to freezing and thawing twice. The slices of meat were defrosted during the broiling process, and then the cooked slices were frozen immediately with dry ice to arrest oxidative changes during grinding. The control slices also were subjected to the freezing with dry ice. Perhaps this procedure contributed to the low mean TBA numbers, all of which were below one (Fig. 1). On the other hand, Zipser *et al.* (1964) reported no significant change in TBA numbers in samples of cooked beef due to freezer storage.

It is possible that broiling just prior to TBA analysis affected the TBA values due to volatilization of some of the TBA-reactive constituents. However, Kwon *et al.* (1964) stated that malonaldehyde arising from lipid oxidation exists in the non-volatile enolate anion in moist foods such as meats.

The preroasting of the beef for "roasteaks" may not be sufficient to convert myoglobin to the hemichromogen form, which is catalytic for lipid oxidation. The color of a cross section of the large cut of preroasted beef as prepared for "roasteak" indicated that both the ferric and ferrous forms of the heme pigment were present. Roughly two-thirds of the area exposed on slicing was the bright red color typical of the ferrous form of myoglobin. The perimeter was brown suggesting that the iron in this area was in the ferric form.

Objective and subjective measurements. None of the correlation coefficients between mean TBA numbers and mean sensory scores for beef prepared by variations of the "roasteak" procedure for each storage period were significant (Table 8). However, several authors (Tarladgis *et al.*, 1960, and Zipser *et al.*, 1964) reported significant rank correlations between TBA numbers (distillation method) and sensory scores for odor. In their experiments, the test medium was cooked (70°C or 158°F) ground fresh pork held in refrigerator and/or freezer storage. The difference in degree of doneness, magnitude of rancidity, and the broiling of the meat just prior to judging may account for the lack of agreement in findings between this work and that of other researchers.

Tarladgis *et al.* (1960) reported that the threshold range of TBA numbers for detection of off-odor in cooked pork was approximately 0.5–1.0 when malonaldehyde was measured by the distillation method. When the extraction method was used to determine TBA numbers, Tarladgis *et al.* (1964) considered the threshold range for detection of rancid off-odor in cooked pork to be 0.1–0.2. Thus, while the threshold value for detection of rancidity has been established for cooked meats, the TBA number denoting the threshold of unacceptability has not been identified. The magnitude of the TBA number is dependent upon the method of determination. The TBA numbers from the extraction procedure as used in this study are approximately one-half the magnitude as those calculated from the distillation procedure on identical samples of raw pork (Witte, 1966).

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